

SIGNAL AND ENERGY DETECTION METHODS IN COGNITIVE RADIO

A THESIS SUBMITTED IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE
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**Bachelor of Technology
In
Electronics and Instrumentation Engineering**

Under the aegis of
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CERTIFICATE

This is to certify that the thesis entitled “***Signal And Energy Detection Methods in Cognitive Radio***” submitted by Basudev Nayak (Roll no: 111EI0104) in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Electronics and Instrumentation at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in thesis has not been submitted to any other university/ institute for the award of any Degree or Diploma.

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Date-

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1. ABSTRACT

In present day communication, wireless communication has turned into the most mainstream communication. Because of this developing demand on wireless communication applications has put a great deal of limitations on the accessible radio spectrum which is restricted and valuable. In settled spectrum assignments there are numerous frequencies that are not being appropriately utilized. So cognitive radio helps us to utilize these unused frequency bands which are additionally called as "White Spaces". This is an extraordinary way to deal with enhance usage of radio electromagnetic range. In securing the cognitive radio there are 4 vital methods.

In this paper i am going to discuss about the first and most important method to execute cognitive radio i.e., "spectrum sensing". spectrum detecting serves to identify the unused gaps (underutilized groups of the range) giving high spectral resolution ability. In this paper, study of signal detecting systems is introduced. The difficulties and issues included in usage of range detecting systems are talked about in subtle element giving similar investigation of different techniques.

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3. LIST OF ABBREVIATIONS

BPSK – Binary Phase Shift Keying

CP – Cyclic Prefix

CR – Cognitive Radio

CSS – Cyclostationary Spectrum Sensing

DARPA- Defense Advance Research Products Agency

DFT- Discrete Fourier Transform

FCC – Federal Communications Commission

FFT- Fast Fourier Transform

ICI – Inter Channel Interference

LAN- Local Area Network

MBMS - Multimedia Broadcast and Multicast Services

OFDM – Orthogonal Frequency Division Multiplexing

PCS - Personal Communication Services

PD - Probability of Detection

PU - Primary Users

SDR – Software Defined Radio

RKRL – Radio Knowledge Representation Language

STFT - Short Time Fourier Transform

SU - Secondary Users

WLAN - Wireless Local Area Network

WMAN - Wireless Metropolitan Area Network

WPT - Wavelet Packet Transform

4. INTRODUCTION

As the need of wireless communication applications are expanding the accessible Electromagnetic Spectrum band is getting swarmed day by day. As indicated by numerous scrutinizes it has been observed that the assigned range (licensed spectrum) is not used legitimately due to static allotment of range. It has ended up most hard to discover empty groups either to set up another administration or to upgrade the current one. In request to beat these issues we are going for "Dynamic Spectrum Management" which enhances the utilization of range.

Cognitive Radio deals with this dynamic Spectrum Management guideline which illuminates the issue of range underutilization in wireless communication in a superior way. This radio gives an exceptionally solid correspondence. In this the unlicensed frameworks (Secondary users) are permitted to utilize the unused range of the authorized clients (Primary users). Cognitive radio will change its transmission parameters like wave structure, convention, working recurrence, organizing and so forth based on the interaction with environment in which it operates.

Chapter 1

INTRODUCTION TO COGNITIVE RADIO

1.1 COGNITIVE RADIO

Cognitive Radio (CR) is a framework/model for wireless communication. It is based on programming characterized radio which is a rising innovation giving a stage to adaptable radio frameworks, multiservice, multi-standard, multiband, reconfigurable and reprogrammable by programming for Personal Communication Services (PCS). It utilizes the approach of detecting and gaining from nature and adjusting to factual varieties progressively. The system or remote hub changes its transmission or gathering parameters to impart productively anyplace and at whatever time keeping away from impedance with authorized or unlicensed clients for effective use of the radio range.

Intellectual modules in the transmitter and recipient must work in a congruous way which is attained to through a criticism channel associating them. Beneficiary is empowered to pass on data on the execution of the forward connection to the transmitter. Subsequently CR by need is a sample of a criticism correspondence framework .

The idea was initially started by Defense Advance Research Products Agency (DARPA) researcher, Dr. Joseph Mitola and the result of that idea will be IEEE 802.22 , which is a standard pointed at utilizing psychological radio for Wireless Regional Area Network (WRAN) utilizing white spaces as a part of the TV recurrence range while guaranteeing that no unsafe impedance is brought on to the occupant operation, i.e., advanced TV and simple TV, and low power authorized gadgets. IEEE P802.22.1 is a standard being produced to improve hurtful impedance security for low power authorized gadgets working in TV Broadcast Bands in the 700 MHz band. IEEE P802.22.2 is a suggested practice for the establishment and organization of IEEE 802.22 System. IEEE 802.22 WG is a working gathering of IEEE 802 LAN/MAN gauges panel which is contracted to compose the 802.22 standard. The two 802.22 assignment bunches (TG1 and TG2) are composing 802.22.1 and 802.22.2 separately.

1.1a RTL-SDR

RTL-SDR is an extremely modest programming characterized radio that uses a DVB-T TV tuner dongle in view of the RTL2832U chipset. With the joined endeavors of Antti Palosaari, Eric Fry and Osmocom it was discovered that the sign I/Q information could be gotten to specifically, which permitted the DVB-T TV tuner to be changed over into a wideband programming characterized radio by means of another programming driver.

Basically, this implies that a shabby \$20 TV tuner USB dongle with the RTL2832U chip can be utilized as a PC based radio scanner. This kind of scanner ability would have fetched hundreds or even a great many dollars simply a couple of years prior. The RTL-SDR is additionally regularly alluded to as RTL2832U, DVB-T SDR, RTL dongle or the "\$20 Software Defined Radio".

There are numerous other programming characterized radios like the RTL-SDR, however they all have a go at a much higher cost. The FunCube PRO+ is a decent collector like the RTL-SDR, valued at around \$190 USD. There is presently additionally the Airspy (\$200) and SDRPlay (\$300). At that point there are the HackRF (\$300USD) and BladeRF SDRs (\$420 and \$650), which can both transmit and get.

1.1a(i) RTL-SDR Radio Scanner Application

1. Listening to decoded Police/Ambulance/Fire/EMS discussions.
2. Listening to flying machine activity control discussions.
3. Following flying machine positions like a radar with ADSB deciphering.
4. Translating airplane ACARS short messages.
5. Examining trunking radio discussions.
6. Translating decoded advanced voice transmissions.
7. Following oceanic vessel positions like a radar with AIS deciphering.
8. Translating POCSAG/FLEX pager activity.
9. Examining for cordless telephones and child screens.
10. Following and getting meteorological organization propelled climate inflatable information.
11. Following your own particular self dispatched high elevation inflatable for payload recuperation.
12. Getting remote temperature sensors and remote force meter sensors.
13. Listening to VHF beginner radio.
14. Disentangling ham radio APRS parcels.
15. Viewing simple show TV.
16. Sniffing GSM signals.
17. Utilizing rtl-sdr on your Android gadget as a convenient radio scanner.
18. Getting GPS flags and deciphering them.
19. Utilizing rtl-sdr as a range analyzer.
20. Getting NOAA climate satellite pictures.
21. Listening to satellites and the ISS.

1.1b Software Defined Radio

Software Defined Radio (SDR) is a radio correspondence framework where parts that have been normally actualized in equipment (e.g. mixer, channels, enhancers, modulators/demodulators, indicators, and so on.) are rather executed by method for programming on a PC or inserted system. While the idea of SDR is not new, the quickly advancing abilities of computerized gadgets render down to earth numerous procedures which used to be just hypothetically conceivable. Radio parts, for example, modulators, demodulators and enhancers are customarily executed in equipment segments.

1.2 COGNITIVE CYCLE

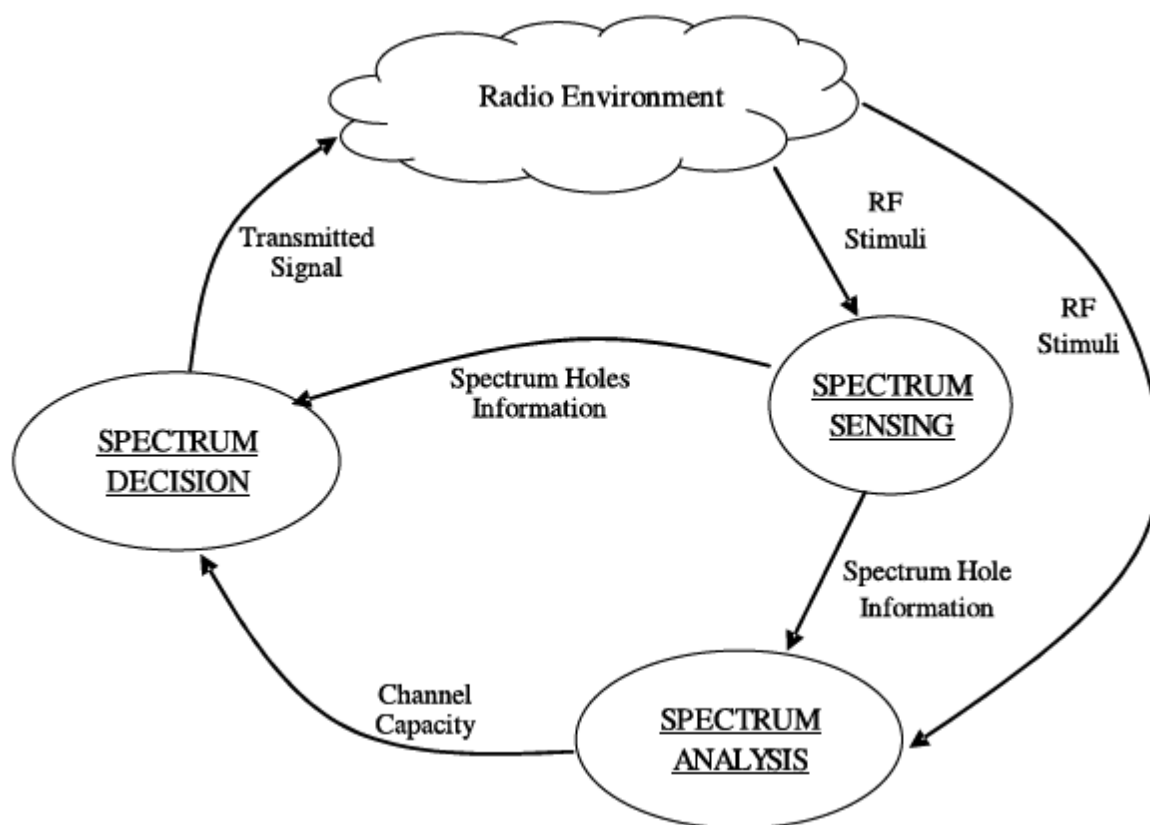


Figure 1 - Cognitive cycle

1.3 COGNITIVE RADIO'S CAPABILITIES

1.3a Spectrum Sensing

spectrum detecting is the capacity to quantify, sense and be mindful of the parameters identified with the radio channel attributes, accessibility of range and transmit power, obstruction and clamor, radio's working surroundings, client necessities and applications, accessible systems (frameworks) and hubs, nearby strategies and other working confinements. It is done crosswise over Frequency, Time, Geographical Space, Code and Phase.

1.3b Spectrum Analysis

Spectrum Analysis is taking into account range detecting which is dissecting the circumstance of a few variables in the outer and inside radio environment, (for example, radio recurrence range use by neighboring gadgets, client conduct and system state) and discovering the ideal correspondence convention and changing recurrence or channel likewise. It is otherwise called channel estimation.

1.3c Spectrum Decision Making

Range Decision Making calls for reconfiguration for the channel and convention needed for always adjusting to portable changing situations and modify ment of yield power or even adjustment of transmission parameters, (for example, balance positions (e.g. low to high request QAM), variable image rates, distinctive channel coding plans) and qualities by the Cognitive radio gadgets. CR ought to have the capacity to utilize numerous recieving wires for obstruction nulling, limit build or extent augmentation.

1.4 COGNITIVE RADIO'S KEY BENEFITS

Cognitive Radio offers optimal diversity (frequency, power, modulation, coding, space, time, polarization and so on) which leads to:

- **Spectrum Efficiency-** The basic purpose of implementing CR will allow the spectrum to be met in future demand.
- **Higher bandwidth services-** Interest of MBMS is always on the ascent which will be encouraged by the execution of CR.
- **Graceful Degradation of Services -** At the point when conditions will be not perfect, a agile debasement of administration is given, rather than the less attractive complete and sudden loss of administration. This highlight of CR is essential in giving administrations to the clients particularly when they are portable and the base stations in contact are continually evolving.
- **Improved Quality of Service (QoS)** (latency, data rate, cost etc) - Suitability, availability and reliability of wireless services will improve from the user's perspective.
- **Commercial Exploitation-** CR advances range liberalization (makes it much less demanding to exchange range between clients). Undoubtedly, a business case may exist for turning into a range agent, whereby a third party oversees the exchange between supplier and demander and gets a commission.
- **Benefits to the Service Provider-** More clients in the business sector and/or expanded data exchange rates to existing clients. More players can come in the business sector.
- **Future-proofed product-** A CR is able to change to services, protocols, modulation, spectrum etc. without the need for a user and/or manufacturer to upgrade to a new device.
- **Common hardware platform-** Makers will pick up from economies of scale in light of the fact that they no more need to assemble various equipment variations, rather utilizing a solitary normal stage to run an extensive variety of programming. This likewise supports in quick administration organization.

- **Flexible regulation**-By using a form of policy database, regulation could be changed relatively quickly as and when required, easing the burden on regulators.
- **Emergency service communications**- Joint operations amid real occurrences would advantage extraordinarily as police, flame, rescue vehicle and coastguard could be connected together in one radio with every radio client detecting the range being utilized by alternate gatherings and reconfiguring itself.
- **Benefits to the Licensee**- CR can prepare for range exchanging, where licensees would be permitted to rent a bit of their range rights to outsiders on a worldly, spatial or other suitable premise to recover a percentage of the cost of its 24hr-a-day permit.

Chapter 2

GNU RADIO AND USRP

2.1 GNU Radio

GNU Radio is an open source programming toolbox which comprises of sign preparing squares library and the paste to tie these pieces together for building and sending programming characterized radios . The sign handling squares are composed in C++ while python is utilized as a scripting dialect to attach the pieces together to shape the stream diagram. Drink is use as the interface compiler which permits the incorporation in the middle of C++ and Python dialect. The structure of GNU Radio and USRP SDR. USRP digitized the inflow information from the air and going to GNU Radio through over the USB interface.

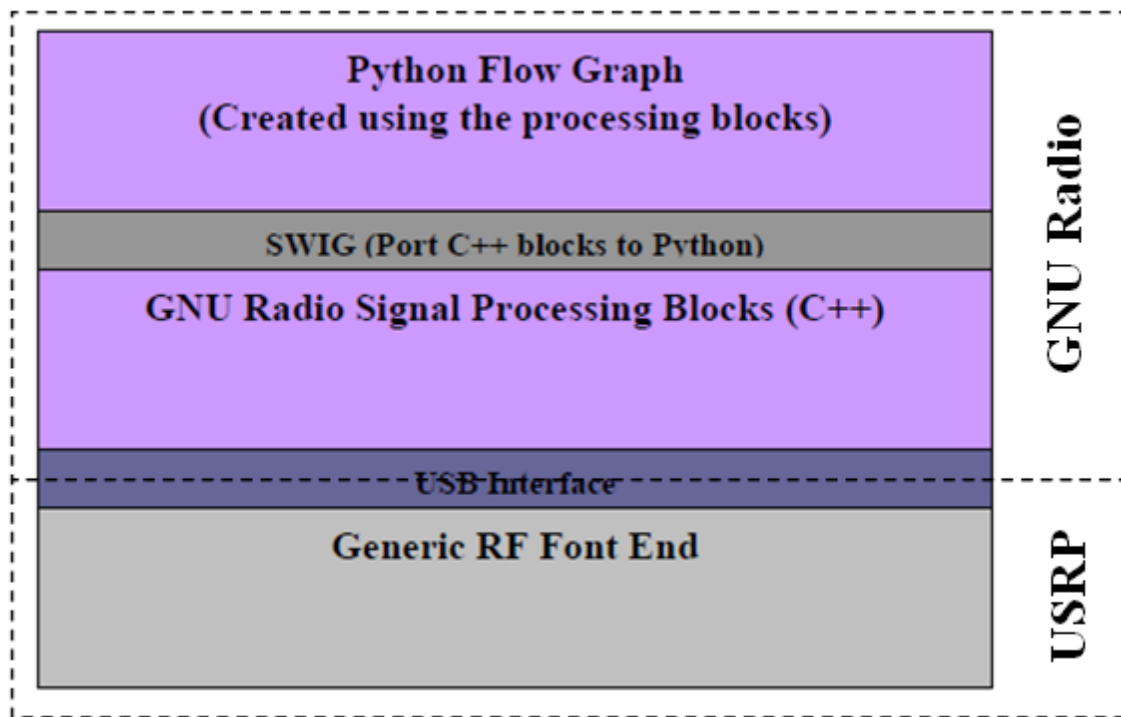


Figure 2 - GNU Radio Components

2.2 Universal Software Radio Peripheral(USRP)

Universal Software Radio Peripheral (USRP) is an adaptable ease stage for programming characterized radios grew by Matt Ettus . USRP comprises of two fundamental sheets; the daughter board and the mother board. The mother board comprises of four 12-bit Analog to Digital Converter (ADC) .

with testing rate up to 64 MS/s, four 14-bit Digital to Analog Converter (DAC) with velocity up to 128 MS/s, two Digital up Converter (DUC) to up believer the baseband sign to 128 MS/s before making an interpretation of them to the chose yield recurrence, a programmable USB 2.0 controller for correspondence in the middle of USRP and GNU Radio and a FPGA for actualizing four Digital Down Converter (DDC) and high rate sign handling. It is fit to all the while transmit and get motion progressively because of completely lucid in every testing clock and local oscillator.

Chapter 3

SPECTRUM SENSING

3.1 SPECTRUM SENSING

Range detecting is the capacity to quantify, sense and be mindful of the parameters identified with the radio channel qualities, accessibility of range and transmit power, obstruction and commotion, radio's working surroundings, client prerequisites and applications, accessible systems (foundations) and hubs, neighborhood arrangements and other working confinements. It is done crosswise over Frequency, Time, Geographical Space, Code and Phase.

3.1a Spectrum Sensing Methods

A number of different methods are proposed for identifying the presence of signal transmission all of which are in early development stage. They are:

- Energy – Detection Based
- Waveform Based
- Cyclostationary – Based
- Radio Identification Based

3.2 ENERGY DETECTION BASED SPECTRUM SENSING

Energy Detection is the most well-known method for range detecting in light of its low computational and usage complexities. It is a more non specific strategy as the recipients needn't bother with any information on the essential client's sign. The sign is recognized by looking at the yield of the energy locator with an edge which relies on upon the commotion floor. The imperative test with the vitality identifier based detecting is the choice of the edge for recognizing essential clients. Alternate difficulties incorporate failure to separate obstruction from essential clients and clamor and poor execution under low flag to-commotion proportion values. PD (probability of detection) and PF (probability of false alarm) are the essential variables for vitality based recognition which gives the data of the accessibility of the range.

3.3 WAVELET TRANSFORM

The Wavelet Transform has as of late picked up a ton of notoriety in the field of sign transforming because of its capacity of giving both time and recurrence data all the while, henceforth giving a period recurrence representation of the signal.

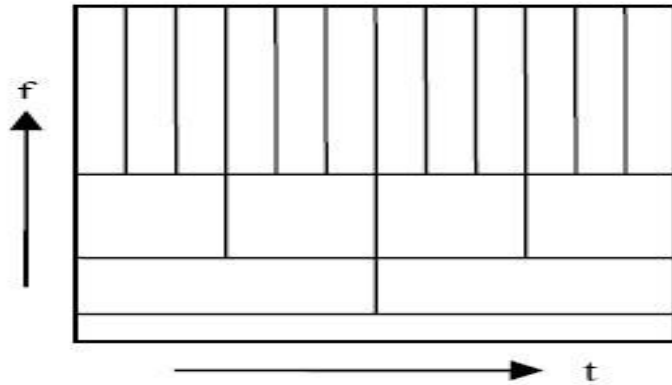


Figure 3 – Resolution of time and frequency in Wavelet Transform

The customary Fourier Transform can just give phantom data about a sign and works for stationary signs though in numerous genuine applications, the signs are non-stationary and needs to be handled in genuine time. The issue with Short Time Fourier Transform (STFT) backtracks to the Heisenberg instability standard which expresses that it is unthinkable for one to acquire which frequencies exist at which time case however, one can get the recurrence groups existing in a period interim. Additionally the window utilized as a part of STFT is of steady length while with Wavelet change we can have multi determination examination i.e. we can

- Analyze the signal at different frequencies with different resolutions.
- Have good time resolution and poor frequency resolution at high frequencies.
- Have good frequency resolution and poor time resolution at low frequencies .

Also it is more suitable for short duration of higher frequency and longer duration of lower frequency components.

3.4 WAVELET PACKET TRANSFORM

For use of interest clamor is principally of high recurrence and the sign of hobby is basically of low recurrence. The wavelet change decays the sign into rough guess (low recurrence) and subtle elements (high recurrence) coefficients, the point of interest coefficients containing much clamor. The straightforward system to denoise the signal will be to basically diminish the size of the subtle element coefficients before utilizing them to remake the sign. This methodology is called thresholding. The point of interest coefficients can't be made zero since they contain some essential highlights of the unique sign. The two diverse methodologies which are typically connected to denoise are hard thresholding and delicate thresholding.

Wavelet packet change is a speculation of wavelet change which continue part both low pass and high pass sub-groups at all scales in the channel bank rough guess and usage. Thus it is suitable to finely recognize the data in both high and low recurrence groups and subsequently is a perfect preparing device for non-stationary time-variable sign.

The following figure is the wavelet packet decomposition tree.

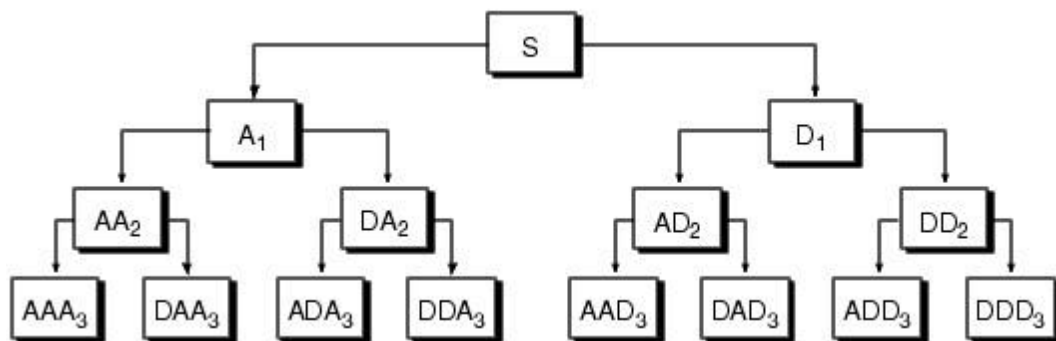


Figure 4– Wavelet packet decomposition tree

Wavelet packet analysis allows the signal S to be represented as $A_1 + AAD_3 + DAD_3 + DD_2$.

3.5 ENERGY DETECTION MODEL BASED ON WAVELET PACKET TRANSFORM

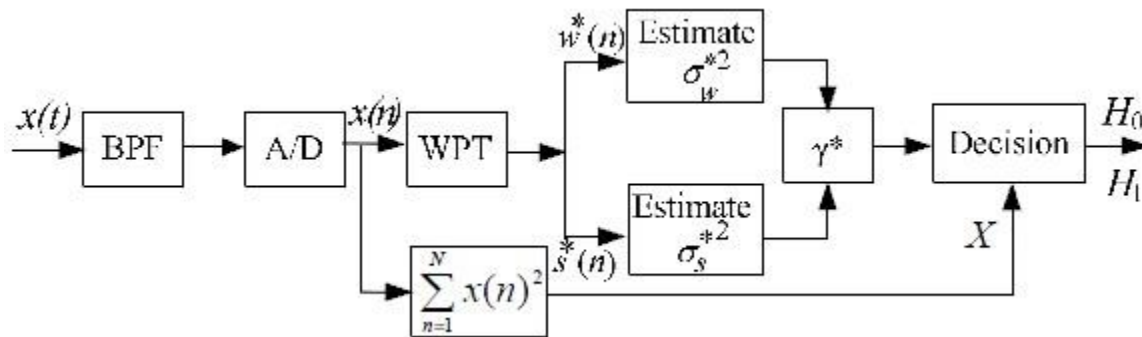


Figure 5 - Block diagram of Energy Detection Model based on WPT

The piece chart is like the least complex vitality based finder however most critically a Wavelet Packet Transform (WPT) square has been presented which appraises the present clamor and sign force, which is imperative for settling edge. The simple sign $x(t)$ in the wake of being changed over into advanced sign $x(n)$ is disintegrated for a certain level identified with the determination obliged and after that is recreated by wavelet parcel deterioration coefficients. What's more, subsequently the clamor power and reproduced sign force is assessed.

3.6 CYCLOSTATIONARY SPECTRUM SENSING

At the point when a transmitted sign is tweaked with a sinusoidal transporter, cyclic prefixes (as in OFDM), code or bouncing groupings (as in CDMA); cyclostationarity is affected i.e. mean, autocorrelation show occasional conduct. This highlight is abused in a Cyclostationary Feature Detector that measures a sign property called Spectral Correlation Function..

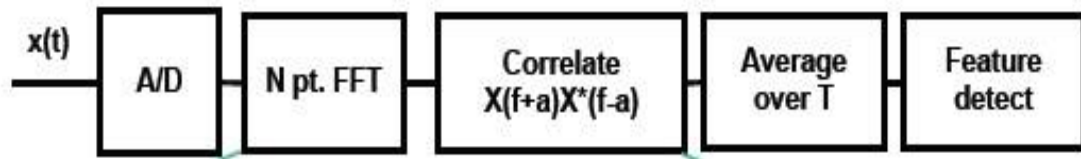


Figure 6- Cyclostationary Feature Detector

3.7 ADVANTAGES & DISADVANTAGES OF CYCLOSTATIONARY

SPECTRUM SENSING

Cyclostationary Spectrum Sensing performs better than Energy identification in view of its commotion dismissal capacity. This happens on the grounds that clamor is absolutely irregular and does not display any occasional conduct. When we have no former learning about essential client's waveform which is the situation, all things considered, then best procedure is cyclostationary highlight discovery.

Chapter 4

RESULTS

&

INFERENCES

4.1 FM signal detected using RTL-SDR

RTL-SDR antenna was connected to the DVB-T(Digital Video Broadcasting-Terrestrial) dongle and the dongle was plugged to the Computer .After that I installed the SDR# software to receive the signal coming from antenna.The obtained FM signal is shown below.To access digital signal coming from dongle,I had to install the zadig software.

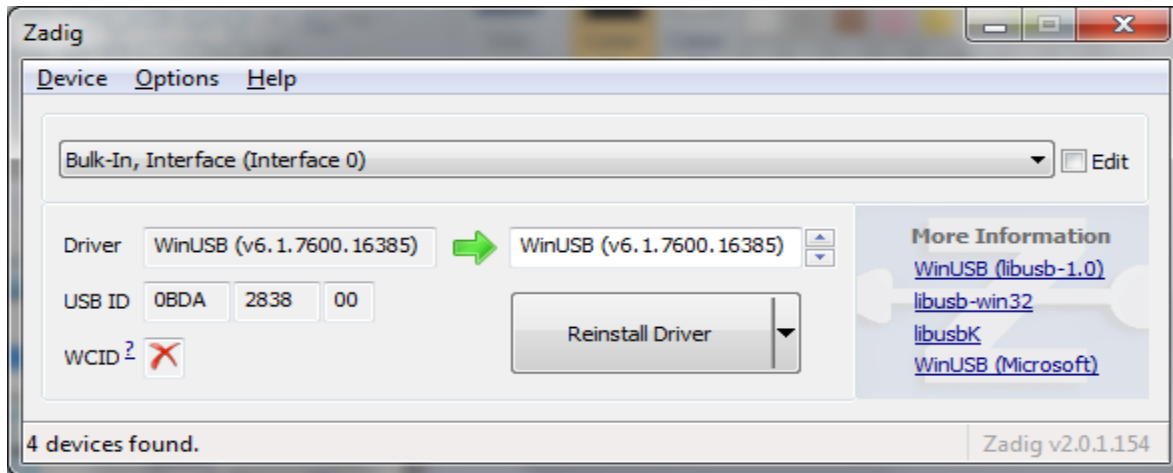


Figure 7-set up zadig software

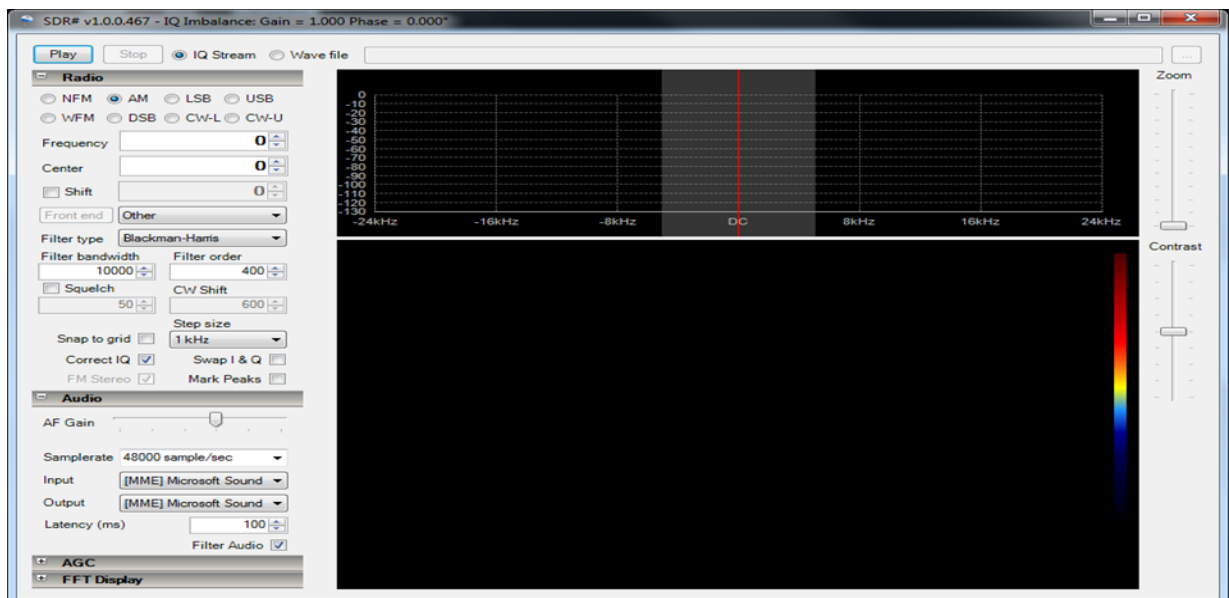


Figure 8-set up of SDR# Software

FM Signal Detected in SDR# software:-

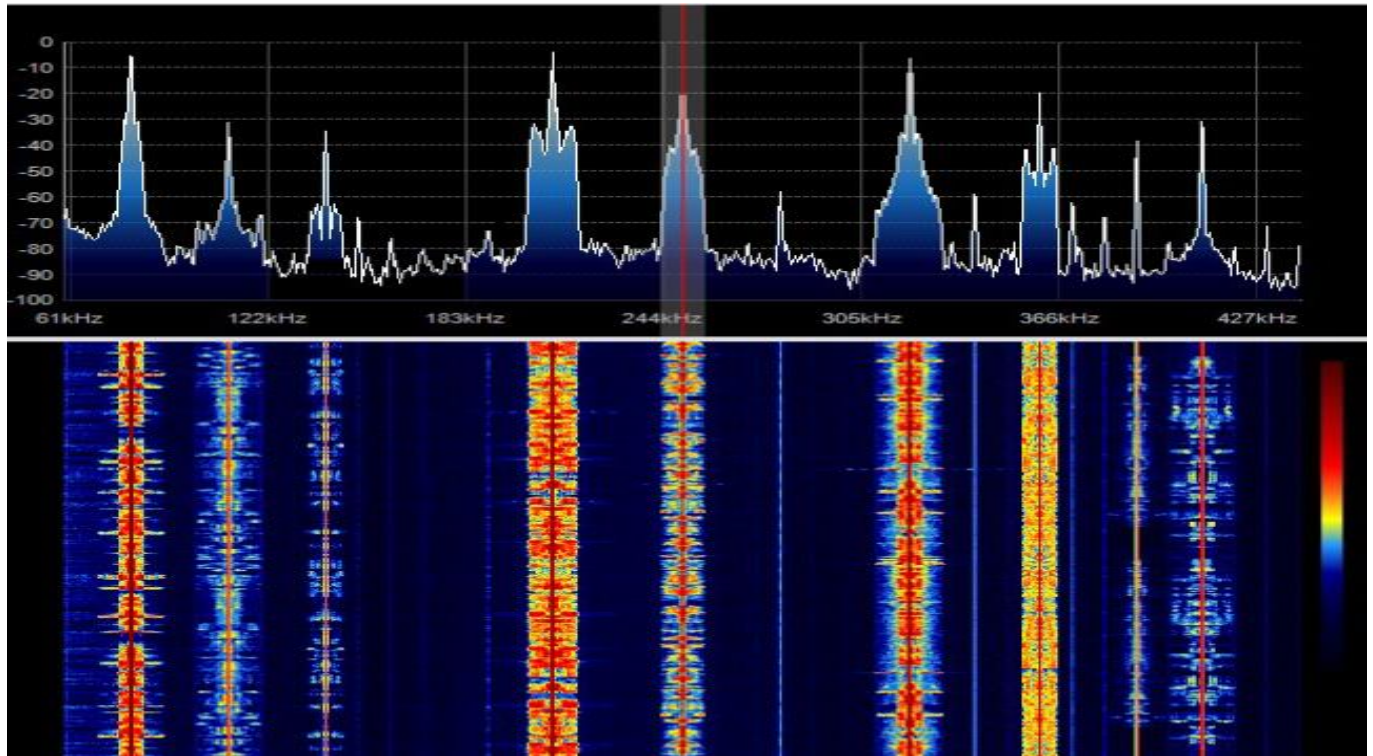
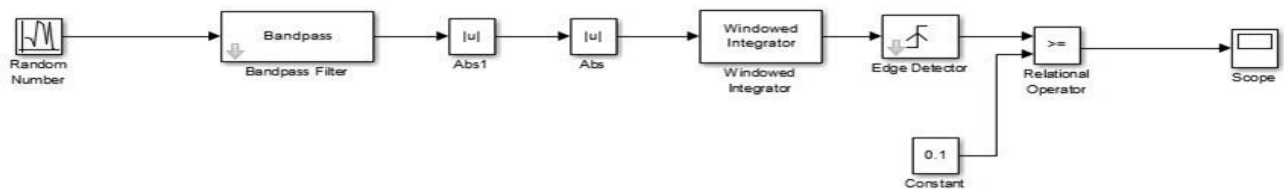


Figure 9- FM signal is detected in SDR#

4.2 Energy detection in Simulink

I took a rand function to generate random signal and then passed through a bandpass filter to get the desired bandwidth. The output of the bandpass filter was passed through two absolute values block and then connected to the integrator block to find out the energy of the signal.

Energy detection of random signal in Simulink



There are two conditions

1. if energy of the signal is greater than 0.1, output will be high.
2. if energy of the signal is less than 0.1, output will be low.

Result

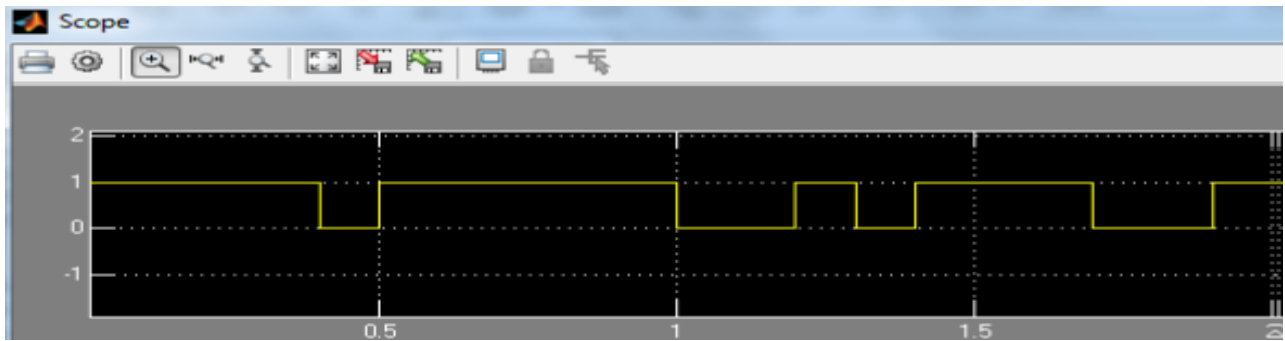


Figure 10-Energy detection using random signal in Simulink

4.2a Energy Detection using RTL-SDR in Simulink

I did set the signal of center frequency 91.7 MHZ ,then connected to the input of RTL-SDR block .RTL-SDR block receives the signal from RTL-SDR antenna .Output of the RTL-SDR block was connected to the lowpass filter with bandwidth 200 KHZ.

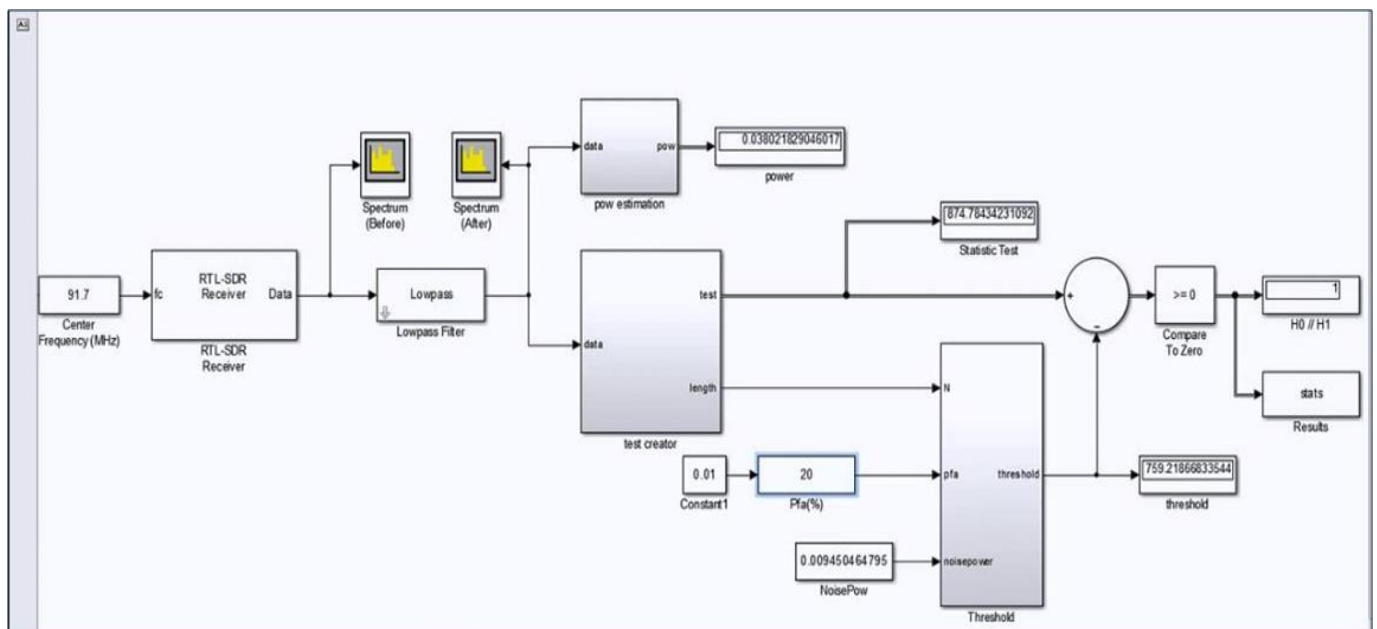


Figure 11-Energy Detection using RTL-SDR in Simulink

H0=Only noise signal (taken as '0'),it is known as secondary user.

H1=Signal with noise(taken as '1'),it is known as primary user.

Here I have taken probability of false alarm(PFA) is 20 percentage.

N=no. of samples(taken 512).

Here statistic value is greater than threshold value,so spectrum is being used by primary user(i.e H1).

Spectrum before passing through the lowpass filter

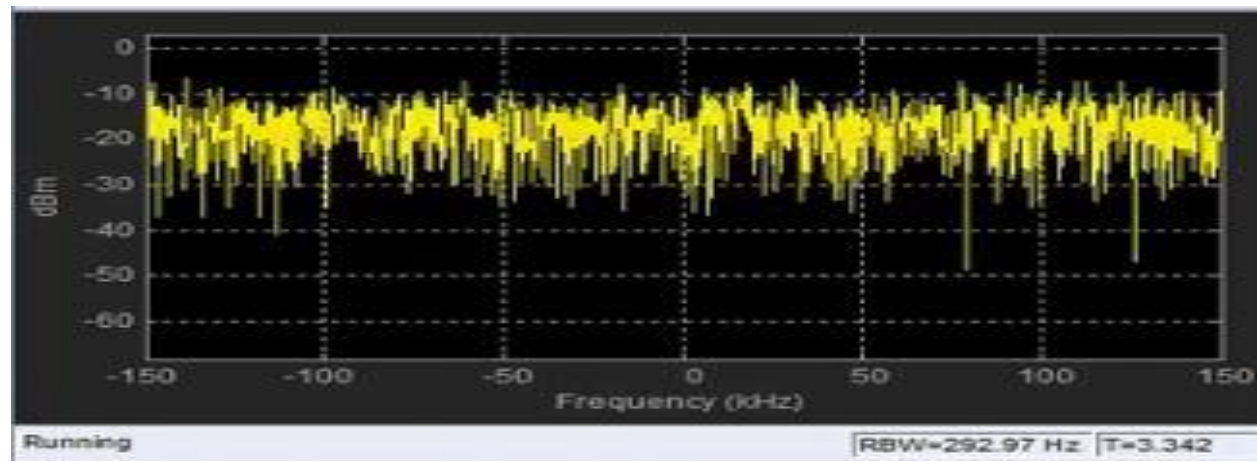


Figure 12-signal detection before passing lowpass filter

Spectrum After passing through the lowpass filter

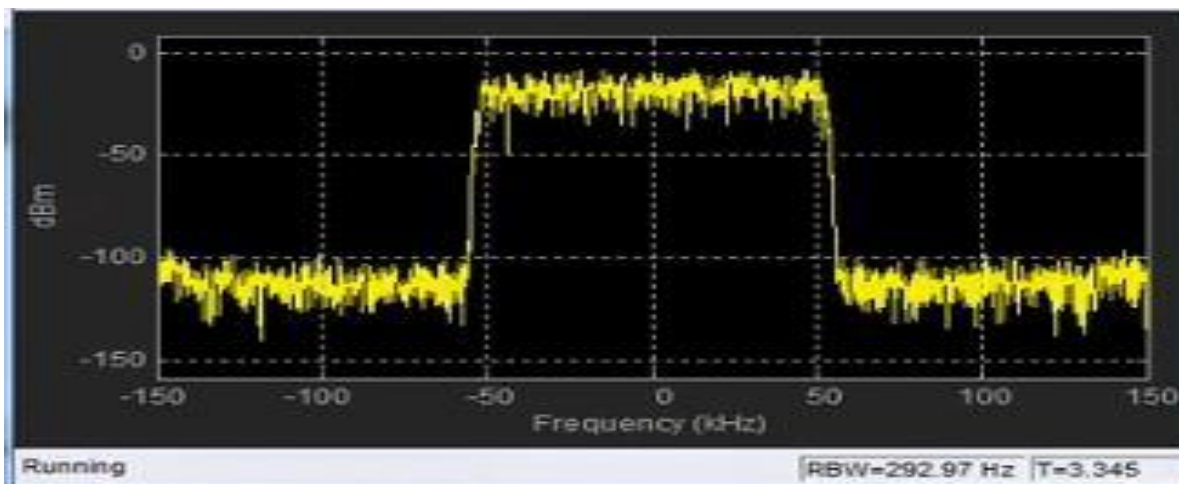


Figure 13-signal detection after passing lowpass filter

4.3 Energy Detection Using RTL-SDR In GNU-Radio

A RTL-SDR source was added to the GNU-Radio Software to get the signal from RTL-SDR antenna and connected to the FFT sink, waterfall sink and constellation sink .

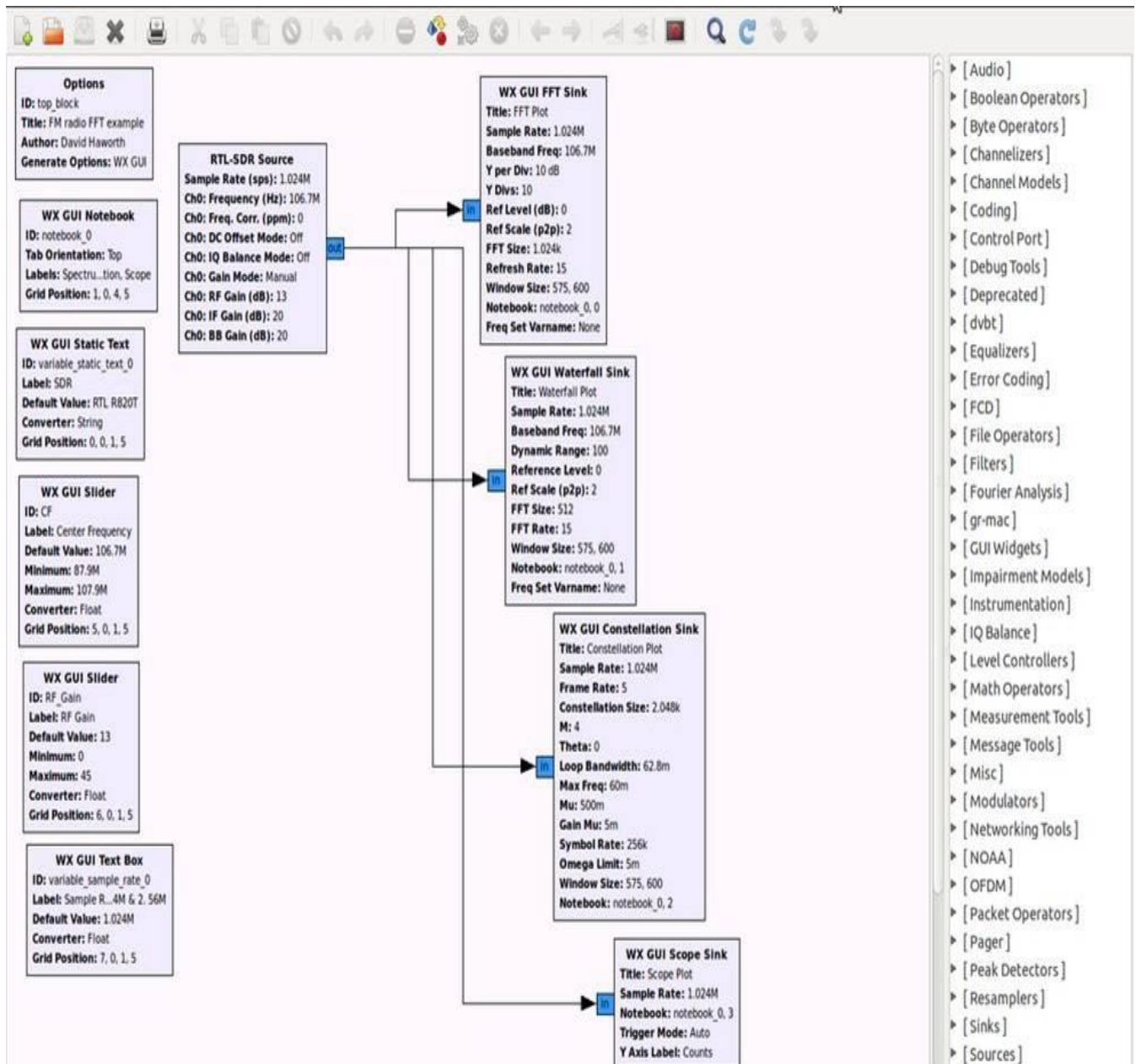


Figure 14-Block digram for Energy detection using RTL-SDR in GNU-RADIO

Figure 15- Waterfall plot shows the signal strength of the Spectrum.

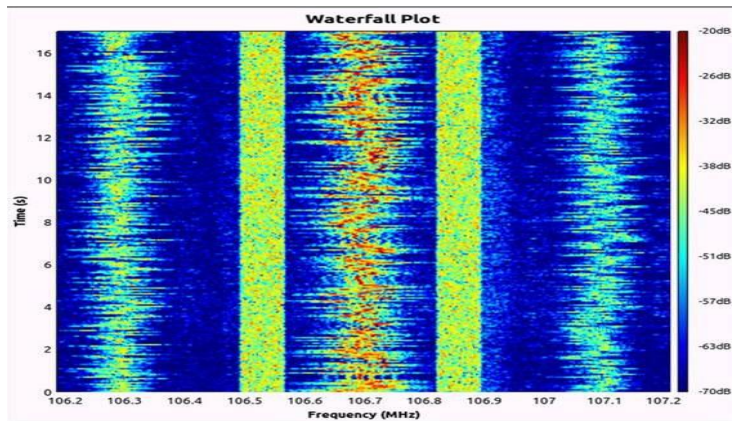


Figure 15-waterfall plot

Figure 16- It shows the fast fourier transform of the received signal by RTL-SDR Source.

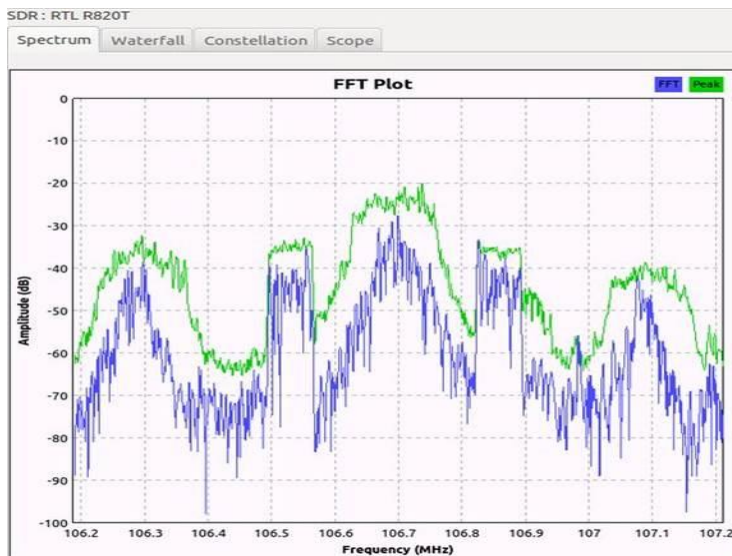


Figure 16-FFT PLOT

Figure 17- Constellation plot shows energy distribution of the spectrum.

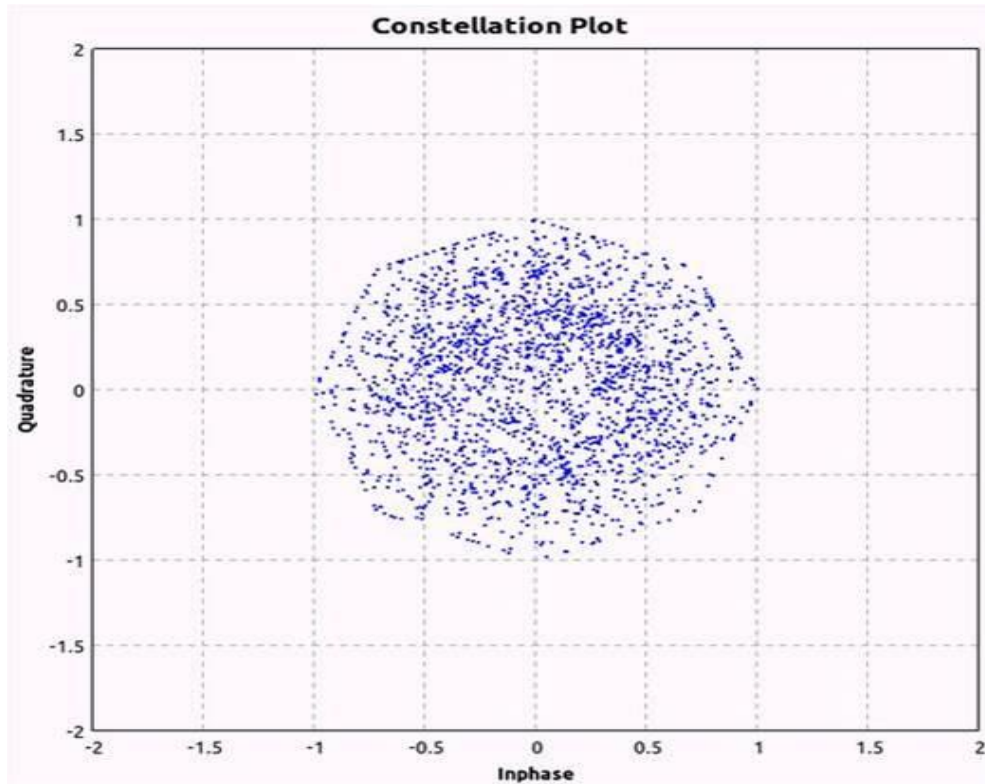


Figure 17-Constellation plot

Constellation Plot-It is the plot between inphase and quadrature.

Inphase-It is the real part of the complex spectrum

Quadrature-It is the imaginary part of the complex spectrum.

Chapter 5

CONCLUSIONS

5.1 Conclusion

Energy Detection Spectrum detecting utilizing subjective radio strategy beats the conventional vitality location system when the clamor was obscure which is the genuine situation. Consequently it is truly a vigorous system for range detecting in Cognitive Radio when the commotion is obscure.

Signal and energy was detected using RTL-SDR in Simulink, SDR# and GNU Radio software. Cognitive Radio did help us to know the spectrum wheather the spectrum is being used or not. Using cognitive radio Method ,unused spectrum can be properly used.However, Cyclostationary spectrum sensing is much more demanding computationally and is more complex than Energy detection spectrum sensing.

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